

Biology Higher Level Internal Assessment

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**Title: Investigating the Relationship Between COVID-19 Vaccination (%) and Mortality
During the Omicron Wave in Selected Middle Eastern and Asian Countries**

Research question: How do the percentages of COVID-19 vaccinations (%) (from December 2020 to December 2022) in the middle-aged populations (from 24 to 48 years) in selected Middle Eastern countries (United Arab Emirates, Qatar, Saudi Arabia, Kuwait, Bahrain, Oman, and Jordan) and Asian countries (Singapore, South Korea, Japan, Malaysia, Thailand, and Vietnam) correlate with COVID-19 mortality (n per million) caused by the SARS-CoV-2 Omicron Variant?

Introduction:

COVID-19, caused by the SARS-CoV-2 virus, is a respiratory disease with a wide range of severity, from mild symptoms to life-threatening complications. Since its detection in December 2019, it has caused a global economic, social, and health crisis.¹

Among the various SARS-CoV-2 variants, the Omicron variant (B.1.1.529) emerged in late 2021 and quickly became dominant due to its high transmissibility and immune evasion. While Omicron's spike protein mutations reduce the neutralizing capacity of pre-existing antibodies, vaccines still offer strong protection against severe illness and mortality. This study investigates how COVID-19 vaccination percentages (%) correlate with mortality rates during the Omicron wave in selected Middle Eastern and Asian countries.

Biological Background and Hypotheses:

The Omicron variant's high transmissibility is attributed to its spike protein mutations, which enhance its ability to bind to **angiotensin-converting enzyme 2 (ACE-2) receptors**² in human cells. This allows the virus to spread rapidly and evade some immune defenses. However, despite reduced neutralization, vaccines remain effective in preventing severe illness and death.³

COVID-19 vaccines, particularly mRNA vaccines, stimulate the immune system to recognize the virus and mount a protective response. Booster doses further enhance immunity, reducing hospitalization risks. As a result, populations with **higher vaccination percentages (%)** are expected to have **lower mortality (n per million)**, even in regions with significant Omicron transmission.⁴

¹ WHO. "Ageing and health." World Health Organization (WHO), 1 October 2022, <https://www.who.int/news-room/fact-sheets/detail/ageing-and-health>.

² Samavati, Lotfi, and Ling Y. Uhal. "ACE2, Much More Than Just a Receptor for SARS-CoV-2." *Frontiers in Cellular and Infection Microbiology*, vol. 11, 2021, National Center for Biotechnology Information, <https://pmc.ncbi.nlm.nih.gov/articles/PMC8236094/>.

³ National Center for Biotechnology Information. *Structure, Function, and Antigenicity of the SARS-CoV-2 Spike Glycoprotein*. National Library of Medicine, 2020, <https://www.ncbi.nlm.nih.gov/books/NBK554776/>.

⁴ Cao, Yunlong, et al. "Omicron Escapes the Majority of Existing SARS-CoV-2 Neutralizing Antibodies." *Nature*, vol. 607, 2022, National Center for Biotechnology Information, <https://pmc.ncbi.nlm.nih.gov/articles/PMC9015596/>.

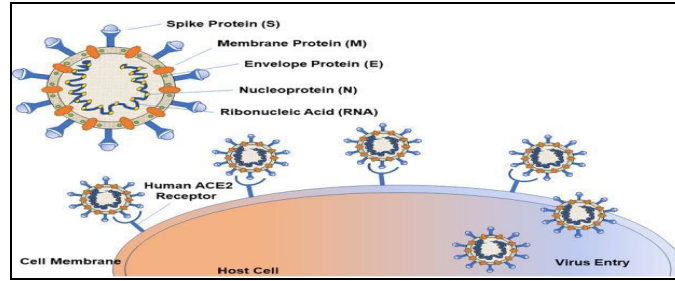


Figure 1: SARS CoV Structure.

Hypothesis:

Table 1: Null and Alternative Hypothesis

Null Hypothesis (H_0)	There is no significant relationship between COVID-19 vaccination (%) and SARS-CoV-2 mortality (n per million) during the Omicron variant wave in selected Middle Eastern and Asian countries. This indicates that any observed correlation between vaccination (%) and mortality (n per million) is due to chance, not a meaningful association.
Alternative Hypothesis (H_1)	Higher COVID-19 vaccination (%) are associated with lower SARS-CoV-2 mortality (n per million) during the Omicron variant wave in selected Middle Eastern and Asian countries. In other words, as vaccination (%) increases, mortality (n per million) are expected to decrease, reflecting the protective effect of vaccines during this period.

Methodology and Materials:

The following parameters and numerical data were taken and assembled through google sheets, from the data repository of John Hopkins University, COVID-19 dashboard, and Our World in Data:

1. The population of each country
2. The median age of the population
3. The percentage of fully vaccinated population in the selected countries
4. The number of deaths of COVID-10 in the selected countries between January 8 and January 21, 2022

Uncertainty in time (days), vaccination percentages (%), and mortality (n per million) could not be obtained due to the nature of using secondary data from official government or global health databases, which do not publish measurement uncertainties.

Justification for Target Country Selection

This study focuses on selected Middle Eastern and Asian countries to ensure comparability in healthcare systems, economic status, and COVID-19 policies while maintaining regional diversity. The criteria for country selection included:

- 1) Data Availability: Countries with reliable and publicly available vaccination and mortality data were prioritized.
- 2) Stable Health Infrastructure: Countries with functional healthcare systems were chosen to minimize variability due to healthcare access disparities.
- 3) Omicron Wave Dominance: Countries where Omicron was the dominant variant during the study period (January 8–21, 2022) were selected.
- 4) Exclusion of War-Affected Nations: Countries experiencing conflict or instability (e.g., Syria, Yemen) were excluded to avoid unreliable reporting.

Table 3: Variables

Independent	Vaccination Percentages (%)	The percentage of the population in each country that is fully vaccinated against COVID-19 as of the study period (January 8-21, 2022). "Fully vaccinated" is defined as having received at least two doses of a WHO-approved COVID-19 vaccine. Booster doses are not included due to inconsistent reporting across countries. The vaccination rate serves as the main predictor variable to determine its correlation with mortality (n per million).
Dependent	Mortality Rates (n computed value)	The number of COVID-19-related deaths per 1,000,000 people in each country during the study period (January 8-21, 2022). This data is collected from John Hopkins University COVID-19 Dashboard and adjusted for population size to ensure comparability between countries. Mortality (n per million) is used as the main outcome variable to assess the impact of vaccination rates.

Table 3: Controlled Variables

Controlled Variables	Method of Control	Reason of Control
Data Collection	All data were collected from John Hopkins Respiratory, COVID-19 dashboard, and Our World in Data.	That to ensure data transparency and consistency.
Fixed Time Frame (Jan 8 to Jan 21, 2022)	Data in this time frame was only used.	To ensure that mortality (n per million) corresponds to the variant Omicron.
Healthcare Infrastructure	Countries with similar healthcare access were included. Public health spending per capita was checked as a reference.	Countries with better hospitals and ICU capacity may have lower mortality (n per million), regardless of vaccination (%)
Natural Immunity	Countries with similar prior exposure to COVID-19 waves were selected to minimize discrepancies.	Some populations had high prior infection rates, reducing mortality (n per million) even with low vaccination (%).
Testing and Reporting Standards	Countries with reliable and standardized reporting were prioritized.	Countries with low testing rates may underreport COVID-19 cases and deaths.
Vaccination Definition	A consistent definition of “fully vaccinated” (two primary doses) was used across all countries.	Some countries define “fully vaccinated” differently (e.g., two doses vs. two doses + booster).

Data Processing & Statistical Methods

To analyze the relationship between Vaccination (%) and COVID-19 mortality (n per million) two statistical tests were done:

1. Pearson Correlation Coefficient

- Used to measure the strength and direction of the relationship between **vaccination (%)** and **mortality rates**.
- Hypothesis tested:
 - **H₀ (Null Hypothesis):** There is no significant correlation between COVID-19 vaccination (%) and mortality (n per million).
 - **H₁ (Alternative Hypothesis):** Higher COVID-19 vaccination (%) correlate with lower mortality (n per million).

2. Linear Regression Analysis

- Used to determine the **extent to which vaccination (%) predicts mortality**(n per million).
- **R² values** were calculated to measure how much **variance in mortality** (n per million) was explained by vaccination (%).

Outliers (countries with unexpectedly high or low mortality) were identified using Interquartile Range (IQR) analysis.

List of countries: *United Arab of Emirates, Qatar, Saudi Arabia, Kuwait, Bahrain, Oman, Jordan, Singapore, South Korea, Japan, Malaysia, Thailand, and Vietnam.*

Table 4: Ethical, Environmental, and Safety Consideration

Ethical Consideration	Environmental Consideration	Safety Considerations
Copyright and Academic Integrity: All data and sources used in this IA were obtained from publicly accessible repositories, such as the John Hopkins University COVID-19 Dashboard and Our World in Data. Proper citations were included to credit original researchers, preventing plagiarism and copyright infringement. This study does not alter or misrepresent any collected data. Data Transparency & Bias: Some governments may underreport COVID-19 deaths for political or logistical reasons. To reduce this risk, data from independent sources and reports were prioritized when available. Selection Bias: The exclusion of war-affected countries was necessary due to data reliability concerns. This limits the generalizability of the findings to nations with stable healthcare systems.	This study relies on pre-existing datasets and does not require physical materials, energy consumption, or waste production. ● No impact on ecosystems, biodiversity, or pollution was introduced. Thus, this study has no direct or indirect environmental impact.	This study is based on data analysis rather than laboratory experiments, there are no direct physical risks. Safety in research extends to data security and responsible handling of information. Data Accuracy & Ethical Use: accurately report findings and avoid misinterpretation that could lead to misinformation about COVID-19 vaccination efficacy.

Table 5: Raw Data of Mortality Number in each Country

Country Name	Mortality (n of deceased due to SARS-CoV-2 between January 8 to January 21)
United Arab of Emirates	23.00
Qatar	19.00
Saudi Arabia	11.00
Kuwait	9.000
Bahrain	5.000
Oman	2.000
Jordan	288.0
Singapore	11.00
South Korea	622.0
Japan	60.00
Malaysia	271.0
Thailand	287.0
Vietnam	2749

Table 6: Raw Data of Number of Vaccinated individuals in each Country

Country Name	COVID Vaccination (n of Vaccinated individuals from SARS-CoV-2 between January 8 to January 21)
United Arab of Emirates	9,227,610.0
Qatar	933,731.00
Saudi Arabia	23,323,974
Kuwait	3,228,262.0
Bahrain	1,182,337.0
Oman	2,936,528.0
Jordan	3,695,056.0
Singapore	4,684,365.0
South Korea	39,214,203
Japan	99,706,744
Malaysia	19,897,976
Thailand	46,316,277
Vietnam	55,259,562

Processed Data:

To calculate the mortality rate I have done the following equation:

$$COVID19 \text{ Mortality Rate} = \frac{\text{Number of Deaths due to COVID19}}{\text{Total population of a country}} \times 1,000,000$$

The number of deaths will be taken in the period between January 8 and January 21 2022, and then rounded to the nearest integer.

Sample calculation:

$$\text{For United Arab of Emirates: } \frac{128}{9,789,054} \times 1,000,000 = 2$$

To calculate the Covid Vaccination percentage I have done the following equation:

$$COVID19 \text{ Vaccination Percentage} = \frac{\text{Total vaccinated population}}{\text{Total population of a country}} \times 100$$

Sample calculation:

$$\text{For United Arab of Emirates: } \frac{9,227,610}{9,789,054} \times 100 = 94.26\%$$

Table 7: Processed Data of Mortality (n per million) in Each Country

Country	Middle Age	Mortality (n of deceased due to SARS-CoV-2 per 1,000,000 people) (rounded to the nearest integer)
United Arab of Emirates	31	2.0
Qatar	32	4.0
Saudi Arabia	29	1.0
Kuwait	35	2.0
Bahrain	31	3.0
Oman	29	0.0
Jordan	24	26
Singapore	42	2.0
South Korea	43	12
Japan	48	0.0
Malaysia	30	8.0
Thailand	40	4.0
Vietnam	33	28

Table 8: Processed Data of COVID Vaccination (%) in Each Country

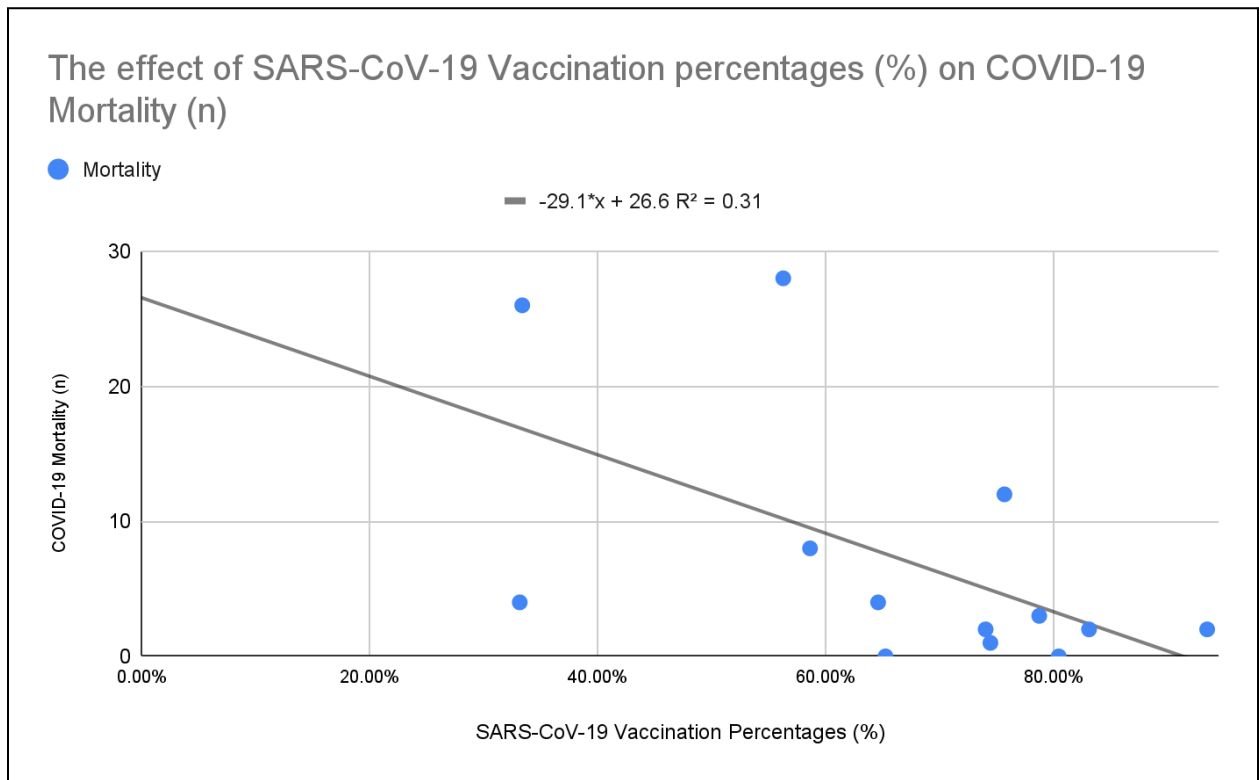
Country	Middle Age	COVID Vaccination (%) (in percentage to unify the ratio of comparison)
United Arab of Emirates	31.00	94.26%
Qatar	32.00	33.17%
Saudi Arabia	29.00	74.45%
Kuwait	35.00	74.03%
Bahrain	31.00	78.73%
Oman	29.00	65.25%
Jordan	24.00	33.39%
Singapore	42.00	83.10%
South Korea	43.00	75.68%
Japan	48.00	80.44%
Malaysia	30.00	58.63%
Thailand	40.00	64.60%
Vietnam	33.00	56.28%

Table 9: Results of the statistical analysis

The one-tailed test of statistical significance and correlation were done using Jamovi⁵.

Vaccination x Mortality	
H_0 : No correlation between amount of vaccinated people and mortality rate	
H_1 : A negative correlation between amount of vaccinated people and mortality rate	
Pearson's regression: -0.557*	P-value: 0.048
Result: the null hypothesis can be rejected, therefore we accept the alternative hypothesis. Which indicates a negative correlation between the number of vaccinated people and mortality rates.	

Statistical Analysis:



Graph 1 : Relationship SARS-CoV-19 Vaccination and COVID-19 Mortality

Negative linear correlation between Vaccination (%) and COVID-19 Mortality Rate: the Pearson correlation coefficient between the vaccination (%) and COVID-19 mortality rates was

⁵ jamovi - open statistical software for the desktop and cloud. (n.d.). <https://www.jamovi.org/>

-0.557. This was done with a p-value of 0.048. This p-value is thus less than 0.05 as shown on the output above which means that it is statistically significant. Therefore as the calculated p-value is less than 0.05 it makes us have a reason to accept the null hypothesis (H_1 ;) while rejecting the null hypothesis (H_0 ;) . Along that the R^2 value of 0.31. The R^2 depicts the extent to which the dependent variable (Mortality) variability is explained or that can be explained by the independent variable(s) (SARS CoV Vaccination(%)). The higher the R^2 the more connected the data. The 0.31 value corresponds to 31% , hence the model explains 31% of the data and shows that indeed mortality is influenced by vaccination (%). The remaining 69% suggests other factors may have a higher contribution than vaccination (%). The graph shows a statistically significant negative relationship between the percentage of people who have been vaccinated and COVID-19 death rates.

This finding aligns with previous research that confirms that vaccines effectively reduce COVID-19 deaths. High vaccination (%) has been shown to lower mortality rates, particularly in areas with high transmission.⁶ It is not only the effects that the vaccination has on the individual health outcome but also on the general population health outcome and may help to decrease the burden on the health care systems.

Outlier Analysis:

Outliers were identified using the Interquartile Range (IQR) method. The IQR is calculated as follows:

$$IQR = Q3 - Q1$$

$$Lower\ Bound = Q1 - 1.5 \times IQR$$

$$Upper\ Bound = Q3 + 1.5 \times IQR$$

Any mortality (n per million) that falls **below the lower bound** or **above the upper bound** is classified as an outlier. After applying the IQR method, the following countries were identified as statistical outliers:

⁶ Bahl, A., et al. (2021). Impact of Vaccination on COVID-19 Outcomes: A Systematic Review. *Journal of Global Health*, 11.

Jordan (High Mortality Outlier)

Japan (Low Mortality Outlier)

United Arab Emirates (UAE) (Unexpectedly High Mortality)

Singapore (Low Mortality Outlier)

Jordan has a median age of 24 years and a vaccination (%) of only 33% and had 26 deaths per one million people. This high mortality rate in a young population is a cause of concern and this in turn raises questions about the health system, availability of health facilities, and social and economic determinants of health in Jordan.

On the other hand, Singapore is a country with a median age of 42 and having a high vaccination (%) of 83% and had only 2 deaths per 1,000,000. This contrast of the two countries on the graph provides a clear understanding of the factors that are hinged on vaccination, age, healthcare system, and public health management.

Also, Japan with a median age of 48, has a vaccination (%) of 80.44%, also reported zero mortality per one million persons. There could be other reasons for this which include sound health care policies, early prevention mechanisms or other preventive measures. This supports the notion that the role of vaccination (%) cannot be the only determinant of mortality rates as other factors such as the public health system, health care seeking, and demographic characteristics also matter.

For instance, countries such as the United Arab Emirates have high vaccination (%) and have registered high mortality rates showing that vaccination is not an assurance for protection against severe outcomes as evidenced by its ineffectiveness due to complications in the delivery of vaccines or weak effectiveness of the vaccines administered due to emergence of new variants.

Strengths

Diverse Data Sample:

- This study integrates data from **13 Middle Eastern and Asian countries**, ensuring a broad perspective on **how vaccination (%) influences mortality trends** across different healthcare systems.
- The inclusion of countries with **varied economic backgrounds and public health capacities** enhances the study's reliability and allows for **cross-regional comparisons** that give deeper insights into vaccine effectiveness.

Strong Statistical Analysis:

- The findings are backed by **Pearson's correlation coefficient (-0.557)** and an **R² value of 0.31**, confirming a **statistically significant negative correlation** between vaccination (%) and mortality(n per million).
- These statistical approaches offer a **numerical validation** of the observed trends rather than relying on assumptions or general patterns.

Sample Selection:

- The countries were **carefully selected** based on **reliable data availability, Omicron wave dominance, and healthcare comparability** to avoid inconsistencies in data interpretation.
- Excluding **war-affected nations** ensured that the study focused on regions with **functional healthcare systems**, which **reduces bias from unreliable or missing data**.

Weaknesses and Limitations:

- 1) **Limited to Quantitative Data:** The study does not account for qualitative factors such as vaccine hesitancy, misinformation, accessibility, and socioeconomic influences on vaccination uptake. To address this, Future research should incorporate survey-based data or case studies to capture public attitudes toward vaccination and healthcare accessibility.

- 2) **Variability in Data Transparency:** Some governments may underreport or misclassify COVID-19 deaths. Jordan reported 26 deaths per million despite a low median age, which contrasts with Japan's zero deaths despite an older population. This raises concerns about data reliability across different regions. To address this, future studies should cross-reference mortality data with independent epidemiological sources (e.g., WHO, CDC) and excess mortality studies.
- 3) **Exclusion of Some Countries:** The study removes countries with unreliable data, which limits generalization to nations with stable healthcare systems. To address this, making a parallel study focused on countries with weaker healthcare infrastructure in the future could provide insight into how different health policies affect mortality rates.
- 4) **Potential Confounding Variables:** factors such as age, healthcare infrastructure, and booster shot availability were controlled, others such as underlying health conditions, obesity prevalence, and ICU capacity may have influenced mortality rates. To address this, Future research could apply multiple regression models to assess the specific impact of additional variables such as pre-existing health conditions and hospital admission rates.
- 5) **Exclusion of Qualitative Factors:** The study focuses entirely on numerical data, not taking into consideration policies that impact vaccine uptake and mortality. For instance, the correlation found between high vaccination (%) and low mortality (Singapore: 83% vaccination, 2 deaths per million) suggests public strategies beyond vaccination alone such as public trust in government policies, accessibility of healthcare, and social behavior towards the pandemic. To address this, incorporating qualitative research would provide a fuller understanding of how public perception, misinformation, and government response shape mortality rates.

Provises:

To further extend the research, an investigation on the following can be conducted:

Booster Shots & Vaccine Efficacy

- This study only considers **full vaccination (two doses)**, yet booster programs were widely implemented during the Omicron wave.

- Future research should assess **how booster dose coverage influences mortality rates**, especially since waning immunity and breakthrough infections became key concerns.

Healthcare Infrastructure & Capacity

- Some **highly vaccinated countries still had unexpectedly high mortality rates**, possibly due to **differences in healthcare quality, ICU availability, and pandemic response policies**.
- A comparative study could **investigate whether healthcare infrastructure mitigates COVID-19 fatalities, even when vaccination (%) are similar across nations**.

Economic & Social Determinants of Vaccine Uptake

- **Vaccine hesitancy, misinformation, economic disparity, and healthcare accessibility** all impact how effectively a population can be immunized.
- Future studies should incorporate **surveys or qualitative data** to examine how **public perception, policy effectiveness, and misinformation** influence vaccination success.

Conclusion:

Using statistical analysis, this study demonstrates a significant inverse relationship between COVID-19 vaccination (%) and mortality (n per million) during the Omicron wave. The Pearson correlation coefficient (-0.557) and R^2 value (0.31) indicate a moderate negative correlation, meaning that higher vaccination (%) were generally associated with lower mortality (n per million). The p-value (0.048) confirms the statistical significance of this correlation, leading to the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_1). These findings show the effectiveness of full vaccination in reducing mortality (n per million), particularly in high-transmission periods like the Omicron wave. Countries like Japan and South Korea have older populations and were found with lower than expected mortality (n per million). That is likely due to early and widespread vaccination efforts. This highlights the importance of vaccination as it is very important in reducing the risk of mortality than age alone.

Additionally to vaccination other factors that can influence health include health systems, public health policies and even social factors. The conclusions arrived have an added advantage of illustrating the need for continuous learning to accommodate the ever changing nature of the pandemic in the development of public health measures. Thus, in view of the connection between the obtained results and the research question formulated, it is possible to state the following: vaccination is still one of the key measures to prevent Covid but the issue must be addressed employing a multilevel and more efficient strategy

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